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A PROCEDURE TO ALLOCATE THE  
ANNUAL STOCKING OF SALMONIDS  
IN THE WISCONSIN WATERS OF  
LAKE MICHIGAN

By

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## ABSTRACT

The sport fishery in the Wisconsin waters of Lake Michigan depends on the annual stocking of 5.5-7.5 million salmonids. A procedure was developed to recommend the species, life stage, numbers, and geographic distribution of salmonids to stock annually. Recommendations developed from the procedure are intended to maximize angler opportunity and catch of salmonids except lake trout. Lake trout numbers recommended to be stocked are developed externally from the procedure and are distributed based on an objective of population reestablishment. Primary inputs to the procedure are angler species preferences and the desired catch (numbers) from the Wisconsin waters of Lake Michigan. The proposed stocking required to meet the catch objective is calculated by species and then evaluated and potentially reduced based on the expected predation on the forage base. The geographical pattern for distribution of the recommended stocking (except coho salmon) is determined through the use of past catch data and fishery facility availability (e.g., number of boat ramps, feet of pier) in management zones. Distribution of coho salmon uses a separate procedure based on knowledge about migration and catch distribution in relation to stocking sites. Costs are determined for the propagation and distribution of the recommended stocking numbers. Angler catch is predicted for the recommended stocking by fishery (trolling, pier, shore, and stream) and zone in order to allow comparison to the originally specified catch objective.

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## INTRODUCTION

The Wisconsin waters of Lake Michigan support a salmonid sport fishery that has a high recreational and economic value. The fishery has appeal to a wide variety of anglers and can be subdivided into four fisheries: trolling, pier, shore, and stream. In 1982, a seven-month creel survey estimated that anglers in these fisheries expended 4.1 million hours fishing and caught 663,000 trout and salmon from Wisconsin's Lake Michigan waters (Paul T. Schultz, pers. comm.).

Ecologically the Lake Michigan fishery is unique because it is maintained by intensive management manipulations on several exotic species. Native species populations such as lake trout (Salvelinus namaycush), blackfin cisco (Coregonus nigripinnis), and deepwater cisco (C. johannae) became extinct in Lake Michigan during the 1950s (Wells and McLain 1973). The shifts in the Lake Michigan fish community have been attributed to predation and competition by exotic species, sea lamprey (Petromyzon marinus), alewife (Alosa pseudoharengus) and rainbow smelt (Osmerus mordax), and to commercial overfishing (Smith 1968, 1970; Wells and McLain 1973; Crowder 1980).

Sea lamprey control with chemicals began in 1960, when the U.S. Fish and Wildlife Service began treating Lake Michigan tributaries with a toxicant selective for lamprey larvae. The purpose of the control program was to reduce the predatory effects of the adults in Lake Michigan by reducing juvenile numbers. The program was highly successful such that by 1966 adult lampreys were reduced to 10% of their 1960 densities (Smith 1971). Low numbers of adults, however, continued to spawn in the streams, and thus, required that the control program be continued indefinitely.

With sea lampreys being controlled and with an abundance of alewife as forage, state and federal agencies began stocking a variety of salmonids into Lake Michigan. In Wisconsin waters, the first salmonid species stocked was the rainbow trout (Salmo gairdneri) in 1963, followed by lake trout in 1965, brown trout (Salmo trutta) in 1966, brook trout (Salvelinus fontinalis) in 1967, coho salmon (Oncorhynchus kisutch) in 1968, and chinook salmon (O. tshawytscha) in 1969. Of the species stocked, only the lake and brook trout were indigenous. Each of the species stocked functioned as top predators with alewife as an important component of their diets.

Survival of the stocked salmonids was sufficient that a sport fishery rapidly developed. By 1972, angler effort in Wisconsin waters was estimated as 1.9 million hours with a catch of 165,000 trout and salmon (Paul T. Schultz, pers. comm.). Natural reproduction of the salmonids did not occur in the state's waters; thus, stocking increased as demand for the fishery expanded. Wisconsin's Lake Michigan sport fishery currently depends on the annual stocking of 5.5-7.5 million salmonids.

The dependence of the fishery on stocking presents an unusual management opportunity to impact the fisheries in local areas by altering the numbers and species stocked. In Wisconsin, management decisions about stocking are intended to optimize angling opportunities in the trolling, pier, shore, and stream fisheries. The stocking decisions require a knowledge of species life histories (movement, maximum size, catch contribution to a fishery, and survival), availability of fisheries facilities (number of boat ramps, piers,

and streams), and angler's desires. For example, the stocking of chinook salmon in an area where there are few boating facilities may not be wise since the trolling fishery typically accounts for more than 50% of the estimated sport catch.

Stocking decisions must also take into account the ecological limitations of Lake Michigan's forage fish production (Stewart et al. 1981). This step is essential because the functional linkage between prey (alewife, smelt, etc.) and predator (trout and salmon) abundance has been severed through the use of hatcheries. Excessive stocking could result in the local extinction of a forage species, or high mortality or poor growth of the salmonids stocked.

In Wisconsin, stocking decisions in the past have been made on an informal basis by fishery managers within the Department of Natural Resources (DNR). The managers intuitively incorporated many of the fishery variables listed above in the development of stocking decisions. As the fishery expanded, the complexity of the variables that impact stocking decisions similarly increased. Coordination of Wisconsin's stocking program between DNR districts also became difficult as managers' requests for stocking Lake Michigan exceeded the production capacity of the state hatchery system. As a result the need arose to identify formal procedures within which to develop stocking recommendations. Schultz (1979) proposed a method to establish the proportion of the available hatchery fish that should be stocked by county along Lake Michigan. The procedure identified several key variables for further analysis but did not define a final process for the development of stocking recommendations. In addition, stocking rates were not affected by changes in forage fish production.

In this paper, we describe a dynamic process to develop annual salmonid stocking recommendations for geographically specific zones in the Wisconsin waters of Lake Michigan. The procedure assumes that the management objective is to maximize angler catch and opportunity for each species stocked, with the exception of lake trout. Primary inputs to the procedure are angler species preferences and the desired catch (numbers) from the Wisconsin waters of Lake Michigan. In addition, the process requires inputs of data about catch by species by zone, past stocking by species, and average weights of coho and chinook salmon. The salmon weights and past stocking data are used to modify stocking recommendations in order to regulate predation pressure on the forage base. The process has been incorporated into an interactive computer program (Dehring and Krueger 1985) written in Apple Pascal and is available from the authors at cost.

## DESCRIPTION OF STOCKING RECOMMENDATION PROCEDURE

The process to develop annual salmonid stocking recommendations for Lake Michigan can be divided into eight steps (Table 1). These steps are used to determine the stocking numbers and distribution of brook, brown, and rainbow trout, and coho and chinook salmon that is to occur three years in the future. In Wisconsin, stocking quotas are established more than two years in advance in order to coincide with hatchery propagation planning. Stocking recommendations for lake trout have been developed separately (Krueger and Dehring 1986, Dehring and Krueger 1986) and are only used here as an input in order to determine the lake trout predation impact on the forage base.

TABLE 1. Procedural steps, inputs, and outputs in the development of stocking recommendations for salmonid species except lake trout for the Wisconsin waters of Lake Michigan.

Procedural Step	User Input	Output
1. Catch Objective	1. Total catch desired from future stocking	--
2. Species Preferences	1. Species preference for the future catch.	--
3. Calculation of Future Catch by Species	--	--
4. Stocking Required for Catch Objective	---	--
5. Modification of Stocking Based on Forage Availability	1. Stocking by species for the past year. 2. Weight of coho and chinook salmon in the past two years. 3. Number of lake trout to be stocked.	1. Total recommended stocking by species and age for the Lake Michigan waters in Wisconsin.
6. Cost Calculation	--	1. Cost by species to produce the fish required for the recommended stocking.
7. Distribution of Recommended Stocking	1. Number caught last year by species, by zone, by fishery.	1. Species and numbers to be stocked within each management zone
8. Predicted Catch	--	1. Species and numbers predicted to be caught from the recommended stocking.

The first five steps of the recommendation procedure determine the total number, size, and species to be stocked in Wisconsin waters (Table 1). The recommendations are developed from information provided by the user about the catch objective desired from the future stocking, angler or fisheries manager species preferences, weight of age II+ salmon from the past two years, past and proposed stocking by species, and the number of lake trout to be stocked. The number of fish required to be stocked to achieve the catch objective is reduced if the required stocking will result in excessive predation pressure or if forage availability has declined.

The sixth step in the procedure calculates the cost per species to stock the recommended numbers of fish (Table 1). The calculations are based on 1981-82 costs to produce and distribute fingerlings and yearlings of each species within the statewide hatchery system.

The seventh step determines the recommendations for the geographic distribution among management zones of the salmonids to be stocked. This step requires input about last year's catch and the amount of facilities (boat ramps, streams, etc.) available for each fishery (trolling, pier, shore, and stream) for each management zone. The coho salmon stocking distribution is based on a separate procedure that uses knowledge of seasonal movements and the distribution of catch in relation to stocking locations.

The final step predicts catch from the recommended stocking and compares the prediction to the total catch objective specified in the first step. The catch prediction is based on the number of years a species contributes to the fishery and therefore does not represent an annual catch prediction.

#### CATCH OBJECTIVE

The catch objective is an input to the procedure defined as the total salmonid catch in numbers (lake trout not included) to occur from the stocking recommendations. The objective represents the entire catch that could occur over several years from a single stocking event. The catch objective may be converted to an annual catch objective if annual stocking at the recommended levels is conducted over the life of the longest lived species (i.e., chinook salmon, 5 years). The objective is the total catch summed among the trolling, pier, shore, and stream fisheries. The trolling portion of this catch figure includes catch from trailered and charter boats but excludes catch by anglers that use boats that are semi-permanently moored in harbor areas. This exclusion was necessary because the stock-catch ratios (discussed later) were not calculated using catches from moored boats due to a lack of data.

The catch objective should be determined based on a long range planning process since the results of a single stocking will impact the fishery for up to a five-year period. The objective could be developed through an analysis of projected angler demand for the fishery and acceptable angler catch rates. The use of the catch objective in the stocking recommendation process is intended to encourage fisheries managers to first consider the desired results of management before implementation of stocking as a management tool.

The catch objective is used as the foundation of the calculations to determine the recommended stocking numbers. Within the procedure described, the catch objective may not be altered unless the stocking required to achieve the

objective will cause the predation pressure on the forage base to exceed specified levels (discussed later).

### SPECIES PREFERENCES

Species preferences for the Lake Michigan catch are used as an input to the procedure and are expressed as percentages of the catch objective. These preferences are specified by user and include brook, brown and rainbow trout, and coho and chinook salmon.

The species preferences could be determined based on the desires of anglers or fisheries managers. Angler preferences are probably the most desirable source for this input since one goal of the Lake Michigan sport fisheries management program is to maximize angler satisfaction. The data required to determine angler desires should be obtained from surveys that personally interview anglers within each fishery to determine the salmonid species that anglers prefer to catch. Such a survey could be incorporated into annual contact creel survey activities. Currently, no data exists for angler species preferences for Wisconsin's Lake Michigan fishery. An alternative is to use species preferences as specified by fisheries managers. In this case, managers would be required to intuitively assess the desires of the angling public.

### CALCULATION OF FUTURE CATCH BY SPECIES

The third step in the stocking recommendation process is to determine the number of each species to be caught (Table 2). These numbers are calculated by multiplying the catch objective by the species preferences (expressed as ratios). The product equals the catch by species that is to occur from the stocking.

TABLE 2. Example calculations to determine the future catch by salmonid species in the Wisconsin waters of Lake Michigan.

Species	Catch Objective <sup>1</sup>		Species Preferences <sup>2</sup>		Proposed Catch
Brook Trout	600,000	x	0.02	=	12,000
Brown Trout	600,000	x	0.15	=	90,000
Rainbow Trout	600,000	x	0.09	=	54,000
Chinook Salmon	600,000	x	0.47	=	282,000
Coho Salmon	600,000	x	0.27	=	162,000

<sup>1</sup>All fisheries exclusive of lake trout and those fish caught by anglers in moored boats.

<sup>2</sup>The example used approximates the current species composition of catch from Lake Michigan's Wisconsin waters.

## STOCKING REQUIRED FOR CATCH OBJECTIVE

The next step in the stocking recommendation procedure is to determine by species the number and size of fish that are required to be stocked to produce the catch specified in the previous steps. This step uses stock/catch ratios that were calculated by species based on past stocking and catch data from the Wisconsin waters of Lake Michigan (Table 3). The data used were the number of fingerlings and yearlings stocked during the years that contributed to the 1980-82 catch. For example, the brook trout catch during 1980-82 was assumed to be derived from plants made in 1979, 1980, and 1981 (Table 3). Catch for each species was calculated based on data from annual creel surveys and from a catch report system required of charter boat operators. Estimates of catch by anglers that use semi-permanently moored boats were not available for these years.

The number of salmonids to be stocked is determined by multiplying the species catch objective by the stock/catch ratio for that species (Table 4). The product calculated is then multiplied by the ratio of yearlings and fingerlings typically stocked (from the past stocking data) to determine the numbers of each life stage to be planted. The method described above assumes that the salmonids caught in Wisconsin are derived primarily from fish stocked in Wisconsin waters which is not valid for coho salmon.

The coho salmon stock/catch ratio is an unusually low value when compared to the other species ratios. The low value is due to the high contribution to the catch by coho stocked in other state's waters. Patriarche (1980) estimated that only 24% of age II+ cohos caught by Wisconsin anglers in 1979 were from plants made in Wisconsin. As a result, the number of coho salmon proposed to be stocked by Wisconsin will only impact a small portion of the total coho catch in Wisconsin.

TABLE 3. Calculation of stock/catch ratios by species in the Wisconsin waters of Lake Michigan.

Species	Years	Stocking (numbers)			Annual Average	Catch (numbers)		Catch/ Stock	Stock/ Catch
		Fingerlings	Yearlings	Total		Years	Annual Average		
Brook Trout	1979-81	144,870	424,607	569,477	189,826	1980-82	8,113	0.0427	23.40
Brown Trout	1978-81	2,006,703	2,021,941	4,028,644	1,057,161	1980-82	54,680	0.0517	19.34
Rainbow Trout	1978-81	2,056,251	1,791,675	3,847,926	961,982	1980-82	35,106	0.0365	27.40
Chinook Salmon	1977-80	7,303,068	0	7,303,068	1,825,767	1980-82	180,176	0.0987	10.13
Coho Salmon <sup>3</sup>	1979-81	0	1,225,417	1,225,417	408,472	1980-82	106,574	0.2609	3.83

<sup>1</sup>Years chosen for calculating annual average number stocked was based on the suspected year class contribution to catch in 1980-82.

<sup>2</sup>Estimated catch is from contact creel census data that included trailered boats, pier, shore, and stream fisheries. Charter boat catches were also included in the annual average calculations based on data from a mandatory catch report system.

<sup>3</sup>Wisconsin stocked coho have been estimated to contribute only 24% to the total coho catch in Wisconsin (from Patriarche 1980). Based on this percentage the actual catch/stock ratio would be 0.0626 and the stock catch ratio would be 15.97.

TABLE 4. Example calculation of the number fish by species that would be necessary to stock in order to achieve the catch objective proposed (example uses 600,000 fish).

Species	Proposed Catch <sup>1</sup>		Stock/ Catch <sup>2</sup>		Proposed Stocking (numbers)	Fingerlings <sup>3</sup> (numbers)	Yearlings <sup>3</sup> (numbers)
Brook Trout	12,000	x	23.40	=	280,800	71,323	209,477
Brown Trout	90,000	x	19.34	=	1,740,600	866,819	873,781
Rainbow Trout	54,000	x	27.40	=	1,479,600	790,106	689,494
Chinook Salmon	282,000	x	10.13	=	2,856,660	2,856,660	0
Coho Salmon	162,000	x	3.83	=	620,460	0	620,460
Total					6,978,120	4,584,908	2,393,212

<sup>1</sup> From Table 2.

<sup>2</sup> From Table 3.

<sup>3</sup> Based on the ratios in the historical stocking data in Table 3.

The procedure described above for coho salmon assumes coho stocking in other states will follow the same trends as in Wisconsin. These states are assumed to provide the balance of the coho stocking required to produce the specified catch in Wisconsin. In order for this procedure to develop proper stocking recommendations, coho salmon management would have to be closely coordinated with other states' fisheries programs.

#### MODIFICATION OF STOCKING BASED ON FORAGE AVAILABILITY

The next step in the procedure is to evaluate and potentially modify the proposed stocking in relation to the available forage. The procedure modifies stocking numbers based on an indirect determination of total predation pressure caused by salmonids already in the lake plus the new fish proposed to be stocked. Total predation pressure is defined as the annual consumption of forage by survivors of stocking events and is compared to the level that occurred in 1982. In addition, stocking is also modified relative to changes in salmon weights between years. The purpose of these modifications is to stabilize predation pressure and to provide a feedback link from prey abundance to predator abundance.

The total predation pressure level in 1982 was chosen as an acceptable level for the regulation of future stocking since salmonid survival and growth were satisfactory that year for the sport fishery. Unless forage availability and production substantially increase, predation pressure greater than the 1982 level could have serious implications to the structure and function of the forage community. For example, bioenergetics models have predicted that as much as 33% of the annual production of alewife may be consumed each year by salmonids stocked in Lake Michigan (Stewart et al. 1981). This level of alewife consumption by salmonids probably contributes to the instability of alewife population densities that has been observed from year to year (Hatch et al. 1981). An increase in predation pressure over current levels could further destabilize alewife population dynamics and unpredictably alter competitive interactions with other forage species.

An index to the total predation pressure in a given year was developed in order to compare the 1982 total predation pressure to the total predation pressure in the year of proposed stocking. The index is calculated through the use of a "predation factor" that standardizes the average annual forage consumption for each species relative to chinook salmon (Table 5; data from Stewart et al. 1981). The predation factor is multiplied by the total number of a species that were stocked to establish the year classes present. The sum of the products among all species equals the index to total predation pressure (Table 5). The contribution of each species to this index is dependent on the species normal life span (e.g., 2 years for coho salmon).

TABLE 5. Calculation of the index to the 1982 total predation pressure (TPP82) exerted upon the forage species of Lake Michigan by salmonids in Wisconsin waters. Method assumed no immigration, emigration, natural reproduction, or changes in survival rates.

Year	Stocking (numbers)						Total
	Brook	Brown	Rainbow	Chinook	Coho	Lake	
1982	283,000	1,861,000	1,042,000	2,521,000	216,000	1,391,000	7,314,000
1981	200,000	1,014,000	1,007,000	1,848,000	318,000	963,000	5,350,000
1980		1,046,000	1,137,000	2,430,000		1,255,000	5,868,000
1979				1,964,000		943,000	2,907,000
1978						994,000	994,000
1977						970,000	970,000
1976						1,045,000	1,045,000
1975						1,054,000	1,054,000
1974						880,000	880,000
1973						1,080,000	1,080,000
Total	483,000	3,921,000	3,186,000	8,763,000	534,000	10,575,000	27,462,000
Predation Factor <sup>1</sup>	0.53 <sup>2</sup>	0.80	0.80	1.0	0.53	0.88	
Predation Pressure	255,990	3,136,800	2,548,800	8,763,000	283,020	9,306,000	24,293,610

<sup>1</sup> From Stewart et al. 1981. Values were determined from Figure 3 and standardized relative to annual consumption by a cohort of chinook salmon.

<sup>2</sup> Brook trout were assumed to be equivalent to coho salmon due to the similar life histories.

TABLE 6. Example calculation of the terms required to calculate the predation adjustment ratio (PAR).

Species		Deceased Year Class	Proposed New Year Class	Planned 1985 Year Class	Planned 1986 Year Class
Brook Trout	Year	1985	1987	1985	1986
	Numbers Stocked	225,000	280,800	225,000	254,000
	Predation Pressure	119,250	148,800	119,250	203,200
Brown Trout	Year	1984	1987	1985	1986
	Numbers Stocked	1,155,000	1,740,600	1,365,000	1,370,000
	Predation Pressure	924,000	1,392,500	1,092,000	1,096,000
Rainbow Trout	Year	1984	1987	1985	1986
	Numbers Stocked	1,365,000	1,479,600	1,130,000	490,000
	Predation Pressure	1,092,000	1,183,700	904,000	392,000
Chinook Salmon	Year	1985	1987	1985	1986
	Numbers Stocked	2,792,000	2,856,700	2,710,000	2,700,000
	Predation Pressure	2,792,000	2,856,700	2,710,000	2,700,000
Coho Salmon	Year	1983	1987	1985	1986
	Numbers Stocked	515,000	620,500	515,000	700,000
	Predation Pressure	272,950	328,800	272,950	371,000
Lake Trout <sup>3</sup>	Year	1987	1987	1985	1986
	Numbers Stocked	970,000	1,000,000	800,000	1,000,000
	Predation Pressure	853,600	880,000	704,000	880,000
Total	Year		1987	1985	1986
	Numbers Stocked	7,022,000	7,978,000	6,745,000	6,514,000
	Predation Pressure	6,053,800	6,790,000	5,802,200	5,642,000

Residual Predation Pressure Index  
After Death of Oldest Age Classes (RPP) = 19,666,000

where RPP = TPP86 - Deceased Predation Pressure Index  
TPP86 = Total Predation Pressure Index in 1986 = 25,720,000  
Deceased Predation Pressure Index = 6,053,800 from this Table.

Predation Pressure Index Attributable to Proposed Stocking (SPP) = 6,790,000

Total Future Predation Pressure Index (TFPP) = RPP + SPP = 26,456,000

Predation Pressure Index Caused by Future Lake Trout Stocking (FLTPP) = 880,000

$$PAR = \frac{TPP82 - FLTPP - RPP}{SPP - FLTPP} = \frac{24,293,610 - 880,000 - 19,666,000}{6,790,000 - 880,000} = 0.93$$

<sup>1</sup>From Tables 4 and 5.

<sup>2</sup>Calculated using the predation factors given in Table 5.

<sup>3</sup>Specified by user of the procedure.

of salmon weight in the past year divided by the salmon weight two years previous (Table 7). The ratio SFI (Salmon Forage Indicator) is calculated as follows:

$$SFI = \frac{(\text{coho salmon weight age II in year } t + \text{chinook salmon weight age I in year } t)}{(\text{coho salmon weight age II in year } t-1 + \text{chinook salmon weight age I in year } t-1)}$$

Coho and chinook salmon weights at the specified ages provide an index to forage production and availability in the previous year. In Wisconsin, the data available for the calculation are taken from chinook salmon in northern Lake Michigan-Green Bay and from coho salmon in southern Lake Michigan (Table 7). The use of these data allows SFI to accommodate potential geographical differences in forage fish availability as well as food habit differences between species. The proposed stocking recommendations are modified by multiplying SFI by the number of fish proposed for stocking.

TABLE 7. Weights of chinook and coho salmon from the Wisconsin waters of Lake Michigan. The values are used to calculate a salmon forage indicator (SFI in Table 8).

Species	Year	Age	Weight (lbs)
Chinook salmon <sup>1</sup>	1984	1+	2.0
	1983	1+	2.7
Coho salmon <sup>2</sup>	1984	11+	4.97
	1983	11+	5.86

<sup>1</sup>Data from coded wire tagged salmon collected at the Strawberry Creek Weir in October 1983 and 1984 (Terrence Lychwick, pers. comm.).

<sup>2</sup>Data from Sheboygan Coho Derby, August 1983 and 1984 (Paul Schultz, pers. comm.).

The two calculations performed by PAR and SFI may be performed within a single operation (Table 8). The product of these calculations is the final number of fish by species recommended for stocking (Table 8). If PAR plus SFI exceed 2 then PAR and SFI are set equal to 1. This rule prevents the proposed stocking numbers from being increased in excess of that required to achieve the specified catch objective. As a result, the procedure gives priority to the catch objective if allowed by forage base abundance. The final recommended numbers for each species are then multiplied by the ratios of fingerlings and yearlings that comprised the data used to compute the stock/catch ratios (Table 3).

The modifications described above will have limited effectiveness in regulating predator abundance in response to short-term forage fish fluctuations in Lake Michigan. The limited effectiveness is due to three factors: 1) a slow response time in hatchery propagation (2-3 year planning cycle), 2) a lack of coordination of salmonid stocking among natural resources agencies of states adjacent to Lake Michigan, and 3) predation inertia within the lake. The slow response of the hatchery system is innate, fixed by the life cycles of the fish propagated. No solution to this problem is foreseeable. Coordination by Lake Michigan states of stocking activities is essential in order to control predation pressure on the forage base. The effectiveness of a reduction in stocking by Wisconsin to protect forage populations could be negligible if other states increase their stocking levels. Lakewide coordination of stocking activities could be administered through the Lake Michigan Committee organized by the Great Lakes Fishery Commission. The problem of predation inertia is caused by stocking that has occurred in previous years. The effect of this inertia is that only a portion of the total predation pressure may be regulated by the stocking levels of a single year.

Considerably more sophisticated techniques could be devised to regulate stocking based on the population dynamics of forage fishes. Such techniques could use the forage consumption rates by age-class for each species balanced against future predictions of forage fish production. Non-salmonid predatory species could also be included in these calculations. In addition, geographically specific differences in predation and forage production could be incorporated into procedures to regulate stocking. Development of these techniques is currently not possible due to a lack of the information required to construct the required population models.

TABLE 8. Example calculation of modifying proposed stocking levels based on indices of predation pressure and forage availability.

Species (numbers)	Proposed Stocking (numbers) <sup>1</sup>		PAR <sup>2</sup>		SFI <sup>3</sup>	Recommended 1987 Stocking	Fingering <sup>5,6</sup> (numbers) <sup>4</sup>	Yearlings <sup>5,6</sup> (numbers)
Brook Trout	280,800	x	0.63	x	0.81	143,000	36,300	106,700
Brown Trout	1,740,600	x	0.63	x	0.81	888,000	442,200	445,800
Rainbow Trout	1,479,600	x	0.63	x	0.81	755,000	403,200	351,800
Chinook Salmon	2,856,700	x	0.63	x	0.81	1,457,000	1,457,000	0
Coho Salmon	620,500	x	0.63	x	0.81	316,000	0	316,000
Total						3,559,000	2,339,000	1,220,000

<sup>1</sup> From Table 4.

<sup>2</sup> From Table 6.

<sup>3</sup>  $\text{SFI} = \frac{\text{Coho Weight 1984} + \text{Chinook Weight 1984}}{\text{Coho Weight 1983} + \text{Chinook Weight 1983}} = \frac{4.97 + 2.0}{5.86 + 2.7} = 0.81$ ; from Table 7.

<sup>4</sup> Rounded to the nearest 1000 fish; differences from these numbers and those calculated by the computer program described by Dehring and Krueger (1985) are due to the rounding procedure used.

<sup>5</sup> Rounded to the nearest 100 fish.

<sup>6</sup> Ratios used are from Table 3.

## COST CALCULATION

The cost to the Wisconsin fish hatchery system to stock the recommended numbers is calculated on a species specific basis. The expenses required to propagate (hatchery costs) and distribute (transportation costs) fingerlings and yearlings by species were tabulated for the 1981-82 hatchery production year and used to calculate the average cost per fish. State hatchery system costs for the recommended stocking are determined for each species by multiplying the cost per fish by the number of fingerlings and yearlings recommended for stocking (Table 9). The sum of the costs among species equals the total cost to the state hatchery system. In the future, the cost by species will have to be updated as new figures become available.

The cost calculation portion of the procedure could be considerably refined and expanded. Costs for the recommended stocking in each management zone could be calculated by using the specific distribution costs to each management zone rather than the average statewide distribution costs as used by the procedure. The recommended stocking for Lake Michigan could also be linked to a statewide hatchery production model which could then chose propagation facilities that are geographically central to the planned distribution pattern for each species in order to minimize transportation costs.

## DISTRIBUTION OF RECOMMENDED STOCKING

The seventh step in the stocking recommendation procedure is to propose where the salmonids should be stocked in the Wisconsin waters of Lake Michigan. The purpose of the distribution procedure described below is to maximize angler opportunity to catch the stocked fish. The distribution of stocked fish is determined by a comparison of management zones in terms of past catch and the facilities available (e.g., number of boat ramps) to allow angler participation in a fishery (trotting, pier, shore, and stream). Coho salmon are distributed based on a separate procedure which incorporates information available about coho movement and catch. Both procedures calculate by species the proportion of the total stocking that is to be distributed within each zone.

Five management zones were established based on county boundaries, administrative boundaries within the Department of Natural Resources (DNR), and approximately equal shoreline distances (Fig. 1). Smaller management zones were not chosen because the stocked fish were assumed to disperse up to 60 miles and affect the adjacent trolling, pier, shore, and stream fisheries. The Green Bay management zone is larger than the other zones and was established because the fishery in this area may function independently due to its geographical semi-isolation from the rest of Lake Michigan. Definition of the Green Bay zone required that Door County be divided between Gills Rock and Northport into east and west sections. Fishery facility measurements were made only in the northern portion of Green Bay since these are the principal waters that contribute to the salmonid fishery. The southern boundary of these waters on the west shore was the southern Oconto County line and on the eastern shore the southern edge of Little Sturgeon Bay.

The percent of the average annual catch that occurs within a zone (Table 10) is used as part of the distribution calculation for each species except coho salmon. The percent catch by zone is calculated based on the past 3 years of catch within each fishery as estimated by creel survey (Append. Tables 1-4).

TABLE 9. Rearing and distribution costs for the salmonids recommended to be stocked in the Wisconsin waters of Lake Michigan.

Species	1981-82 Cost		Stocking (numbers) <sup>1</sup>		Total Cost <sup>2</sup>
	Fingerlings	Yearlings	Fingerlings	Yearlings	
Brook Trout	\$0.089	\$0.248	36,000	107,000	\$29,700.00
Brown Trout	\$0.102	\$0.243	442,000	445,000	\$153,200.00
Rainbow Trout	\$0.099	\$0.225	403,000	352,000	\$119,100.00
Chinook Salmon	\$0.018	—	1,457,000	0	\$26,200.00
Coho Salmon	—	\$0.225	0	316,000	\$71,100.00
Total					\$399,300.00

<sup>1</sup>From Table 8; rounded to the nearest 1000.

<sup>2</sup>Rounded upward to the nearest \$100.

TABLE 10. Distribution of salmonid catch among management zones within the Wisconsin waters of Lake Michigan (based on 1981-83 catch data; Append. Tables 1-5).

Management Zone	Catch by Species (% by numbers)				
	Brook	Brown	Rainbow	Chinook	Coho
Green Bay	2.1	30.6	17.9	18.0	0.2
Eastern Door	7.5	9.7	10.5	4.3	1.3
Kewaunee-Manitowoc	24.1	28.2	22.9	26.9	6.9
Sheboygan-Ozaukee	66.0	19.2	26.7	28.4	33.5
Milwaukee-Kenosha	0.3	12.3	22.0	22.4	58.1
Totals	100.0	100.0	100.0	100.0	100.0

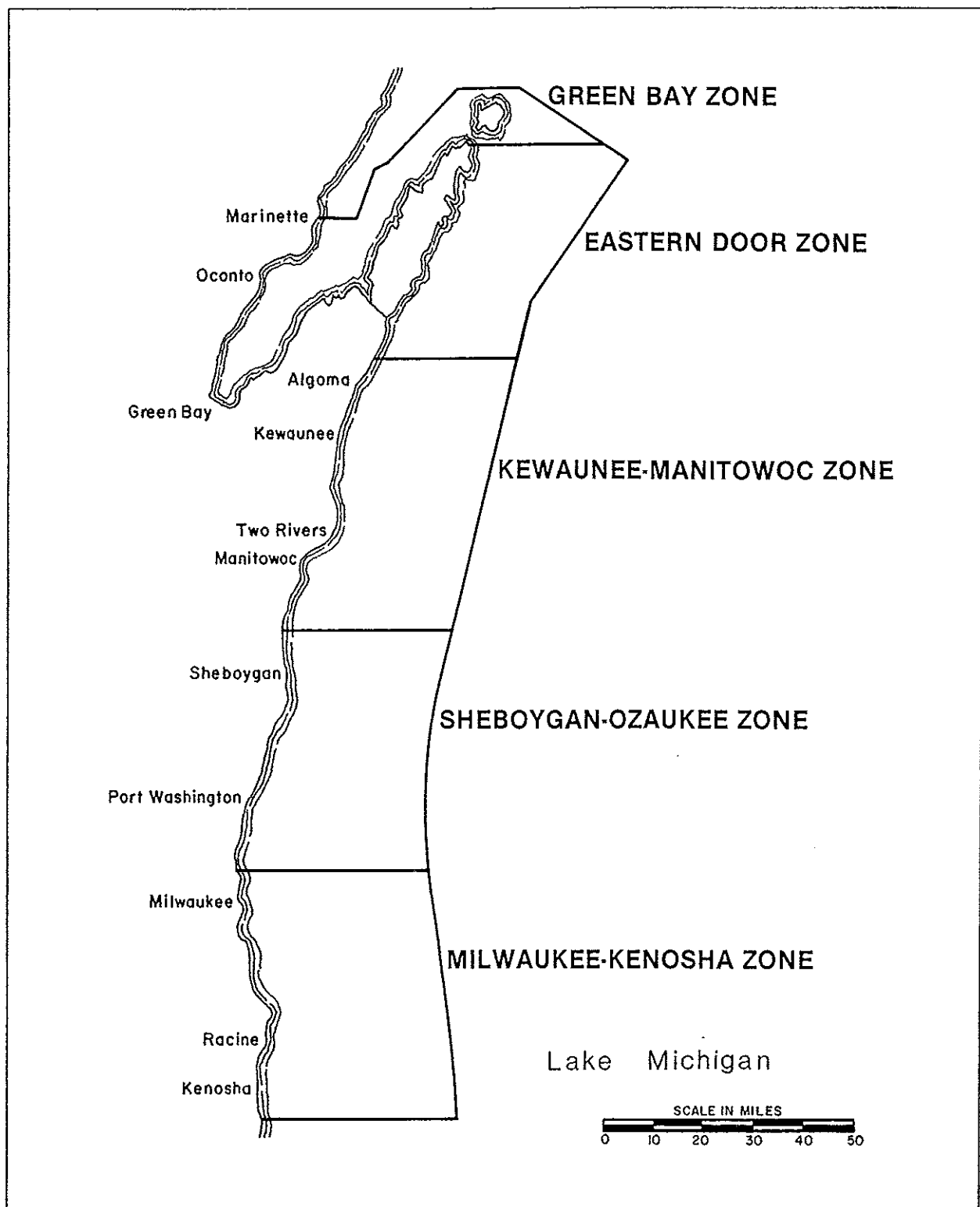


FIGURE 1. Salmonid management zones in the Wisconsin waters of Lake Michigan.

Three-year averages are used in the percentage calculations to reduce the effects of short-term catch fluctuations. In order that the most recent data are used, the catch data matrix is to be updated every year the stocking procedure is used.

Average catch within a zone is related to several variables including angler demand, available fishery facilities, survival of stocked fish, dispersal away from stocking locations, and past stocking practices. The lack of independence from past fish stocking activities interjects short-term management stability between years to the final distribution calculation. This stability, however, does not preclude the occurrence of long-term management changes since the catch data matrix is updated each year. The result is that the angler's expectations based on the experiences of the past fishing season are accommodated although distributional patterns of stocking may be changing in the long term.

The percent of the total catch of a species within a zone determines 40% of the distribution proportion for the species (Table 11). The 40% value was chosen based on a survey of Lake Michigan fish managers that ranked the importance of catch versus fishery facilities in making distribution decisions for stocking (Schultz 1979). The balance of the distribution proportion (60%) is provided by measures of fishery facilities.

Fishery facility measures are intended to index the angling opportunity available within a zone for a particular fishery and are used as part of the distribution calculations for each species except coho (Table 12). The total facility measure for a species within a zone is comprised of four segments, one for each fishery (trolling, pier, shore, and stream).

The trolling portion of the facility measure is based on the boating opportunities for trailered and moored boats (Table 12). The number and proportion of total launching ramp aisles and moored fishing boats were determined for each zone. The proportions of ramp aisles are multiplied by the proportion of the trolling catch that was provided by trailered boat anglers in 1982 in order to weight the contribution of ramp aisles to the trolling facility measure (Table 13). The moored boat proportion is similarly weighted by the 1982 moored boat angler catch proportion. Data for these fisheries were only available for 1982. The sum of the two products equals the proportion of the total boat facility measure contained within each zone.

The facility measures for the pier and shore fisheries are the length measurements of piers and the shorelines within the management zones (Table 12). In most instances, these distances were determined from navigational or U.S. Geological Survey maps. The proportion of the total pier or shoreline length in Wisconsin that occurred within a zone is used as the facility measure for these fisheries in the distribution.

The facility measure for the stream fishery is the stream length available for fishing within a zone (Table 12). The stream length measure used in the stocking distribution calculations varied with salmonid species. Brook and rainbow trout distribution calculations used an equally weighted contribution of stream lengths available to conventional angling (non-snagging) in the spring and autumn (Tables 11, 14; Append. Table 6). In Wisconsin, the stocking of these fish species is not intended to result in contributions to the stream

TABLE 11. Example calculations used to establish the proportional stocking distribution among zones for brook trout.

Management Zone	Catch <sup>1</sup> (% x 0.01)	Contribution of Catch Measure to Distribution	Catch Proportion	Boat Facilities <sup>2</sup> (% x 0.01)	Trolling Catch Proportion <sup>3</sup>	Contribution of Facility Measures to Distribution	Trolling Proportion
Green Bay	0.021	x 0.4 =	0.0084	0.170	x 0.064	x 0.60 =	0.00653
Eastern Door	0.075	x 0.4 =	0.0300	0.082	x 0.064	x 0.60 =	0.00315
Kewaunee-Manitowoc	0.241	x 0.4 =	0.0964	0.296	x 0.064	x 0.60 =	0.01137
Sheboygan-Ozaukee	0.660	x 0.4 =	0.2640	0.136	x 0.064	x 0.60 =	0.00522
Milwaukee-Kenosha	0.003	x 0.4 =	0.0012	0.316	x 0.064	x 0.60 =	0.01213

Management Zone	Fishing Piers <sup>4</sup> (% x 0.01)	Pier Catch Proportion <sup>5</sup>	Contribution of Facility Measures to Distribution	Pier Proportion	Shoreline Distance <sup>4</sup> (% x 0.01)	Shore Catch Proportion <sup>3</sup>	Contribution of Facility Measures to Distribution	Shore Proportion
Green Bay	0.112	x 0.378	x 0.60 =	0.0254	0.291	x 0.238	x 0.60 =	0.0416
Eastern Door	0.058	x 0.378	x 0.60 =	0.0131	0.193	x 0.238	x 0.60 =	0.0276
Kewaunee-Manitowoc	0.346	x 0.378	x 0.60 =	0.0785	0.199	x 0.238	x 0.60 =	0.0284
Sheboygan-Ozaukee	0.171	x 0.378	x 0.60 =	0.0388	0.160	x 0.238	x 0.60 =	0.0228
Milwaukee-Kenosha	0.313	x 0.378	x 0.60 =	0.0710	0.157	x 0.238	x 0.60 =	0.0224

Management Zone	Angling Stream Measure <sup>5</sup> (% x 0.01)	Stream Catch Proportion <sup>3</sup>	Contribution of Facility Measures to Distribution	Stream Proportion	Stocking Distribution (sum of proportions)
Green Bay	0.342	x 0.320	x 0.60 =	0.0657	0.1476
Eastern Door	0.041	x 0.320	x 0.60 =	0.0079	0.0818
Kewaunee-Manitowoc	0.441	x 0.320	x 0.60 =	0.0847	0.2994
Sheboygan-Ozaukee	0.118	x 0.320	x 0.60 =	0.0227	0.3534
Milwaukee-Kenosha	0.058	x 0.320	x 0.60 =	0.0111	0.1178

<sup>1</sup>From Table 10.<sup>2</sup>From Table 13.<sup>3</sup>From Table 14.<sup>4</sup>From Table 12.<sup>5</sup>From Table 15.

TABLE 12. Fishery facilities and resources available to sport anglers within management zones along the Wisconsin shoreline of Lake Michigan.

Management Zone	Launching Ramp Aisles <sup>1</sup> (number)	(%)	Moored Boats July 1983 (number)	(%)	Fishing Piers (feet)	(%)	Shoreline Distance (miles)	(%)	Spring Fishery <sup>1</sup> Stream Length (miles)	(%)	Autumn Fishery <sup>2</sup> Stream Length (miles)	(%)	Stream <sup>3</sup> Length Open to Snagging (miles)	(%)
Green Bay	64	29.3	103	5.5	5,300	11.2	95	29.1	51.3	27.5	41.0	40.8	10.3	12.0
Eastern Door	23	10.6	110	5.9	2,750	5.8	63	19.3	5.4	2.9	5.4	5.4	0.0	0.0
Kewaunee-Manitowoc	72	33.0	497	26.5	16,400	34.6	65	19.9	84.8	45.4	43.2	42.9	41.6	48.3
Sheboygan-Ozaukee	17	7.8	353	18.9	8,100	17.1	52	16.0	34.1	18.3	5.3	5.3	28.8	33.4
Milwaukee-Kenosha	42	19.3	809	43.2	14,900	31.3	51	15.7	11.0	5.9	5.6	5.6	5.4	6.3
Total	218	100.0	1,872	100.0	47,450	100.0	326	100.0	186.6	100.0	100.5	100.0	86.1	100.0

<sup>1</sup>Total Lake Michigan tributary lengths from Appendix Table 6.

<sup>2</sup>Lake Michigan tributary length closed to snagging from Appendix Table 6.

<sup>3</sup>From Appendix Table 6.

TABLE 13. Calculation of a measure of boat facilities available to anglers within management zones along the Wisconsin shoreline of Lake Michigan.

Management Zone	Launching Ramp Aisles <sup>1</sup> (% x 0.01)	Trolling Catch by Trailered Boats (% x 0.01)	Rank Based on Launching Ramps	Moored Boats <sup>1</sup> (% x 0.01)	Trolling Catch by Moored Boats (% x 0.01)	Rank Based on Moored Boats	Boat Facility Measure % (sum of rank x 100)				
Green Bay	0.293	x	0.483	=	0.142	x	0.517	=	0.028	=	17.0%
Eastern Door	0.106	x	0.483	=	0.051	x	0.517	=	0.031	=	8.2%
Kewaunee-Manitowoc	0.330	x	0.483	=	0.159	x	0.517	=	0.137	=	29.6%
Sheboygan-Ozaukee	0.078	x	0.483	=	0.038	x	0.517	=	0.098	=	13.6%
Milwaukee-Kenosha	0.193	x	0.483	=	0.093	x	0.517	=	0.223	=	31.6%

<sup>1</sup>From Table 12.

TABLE 14. Calculation of the stream angling measure within management zones along the Wisconsin shoreline of Lake Michigan. Measure is used in geographic distribution calculations for brook and rainbow trout stocking.

Management Zone	Spring Fishery Stream Length (%)	Autumn Fishery Stream Length (%)	Contribution of Length Type to Stream Measure	Stream Angling Measure (%)
Green Bay	( 27.5	+ 40.8 )	x 0.5 =	34.2
Eastern Door	( 2.9	+ 5.4 )	x 0.5 =	4.1
Kewaunee-Manitowoc	( 45.4	+ 42.9 )	x 0.5 =	44.1
Sheboygan-Ozaukee	( 18.3	+ 5.3 )	x 0.5 =	11.8
Milwaukee-Kenosha	( 5.9	+ 5.6 )	x 0.5 =	5.8

<sup>1</sup>From Table 12.

snagging catch. The stream lengths closed to snagging that are used to compute the autumn measure were based on 1983 regulations and included the Manitowoc River drainage upstream from the Manitowoc Rapids Dam to Clarks Mills and the Oconto River drainage downstream from the Stiles Dam. Separation of stream length measures based on snagging regulations is warranted since in most instances conventional angling and snagging fisheries are spatially mutually exclusive of each other due to conflicts between methods used.

The stream facility measure for the brown trout and chinook salmon fishery is the stream length where snagging is allowed (Table 12). Both species enter the tributary streams in the fall on spawning migrations. At this time of year, the brown trout suffer high mortalities and all salmon die after spawning. As a result, dead fish create a problem along the tributaries for local residents. To alleviate this problem, stream management of these species is intended to inflict a high fishery mortality through snagging in order to reduce the numbers of dead fish. The stocking distribution calculations for brown trout and chinook salmon, therefore, use the proportion of the total stream length open to snagging that occurs within each zone. The stream measures used for the distribution calculations should be updated on a year-to-year basis since snagging regulations frequently change.

The amount that a fishery facility measure contributes to the distribution calculation is determined by the proportion of the total catch of a species that occurs within the particular fishery (Table 15). For example, the trolling fishery provides 6.4% of the total brook trout catch. As a result, the boating facility measure will only contribute 0.064 to the total facility measure within each zone for brook trout (Table 11). The catch proportion within a fishery is determined from the catch data matrices (Append. Tables 1-4) and is based on 3-year averages. Since these matrices should be updated with the most recent catch data, the proportions used to weight the fishery facilities are dynamic and can accommodate long-term changes in fishery performance due to management changes (e.g., changes in the strains stocked).

The proportional stocking distributions of each species except coho salmon are determined by the summation of the catch and fishery facility proportions that exist within a management zone (Table 11). The effect of these calculations is to make relative comparisons of catch and facilities among zones. The objectivity of the comparisons is somewhat diminished because the catch and fishery facility measures are not independent from each other.

The final distribution proportions by species within each zone are multiplied by the earlier computed fingerling and yearling numbers to be stocked (Table 16). The product equals the recommended numbers that should be planted within each management zone.

Coho salmon are distributed by a procedure different from the other salmonids. The procedure used is designed to stock coho in decreasing proportions from north to south along the Wisconsin shoreline. The procedure was developed based on a knowledge about north-south coho migrations and catch from past stockings. Coho salmon (age II) are known to congregate offshore in Illinois and Indiana waters during the winter (Patriarche 1980). In the spring as the water warms, the coho migrate north along the shoreline until they locate their stocking sites (probably by late summer). After this time, they remain offshore from the stocking site until the autumn spawning season when they migrate up tributary streams. Based on these migrational patterns, coho in the past were stocked in decreasing proportions, north to south, from the city of Sheboygan to Kenosha. The theory was that the salmon stocked in Sheboygan would migrate south in the winter and then become vulnerable during their northward migration to anglers in each of the ports south of Sheboygan until late summer. If this theory is correct then the coho catch in the southern Milwaukee-Kenosha management zone should be highest since catch would be based on the combined stocking in the Milwaukee-Kenosha and Sheboygan-Ozaukee zones. Catch north of the Sheboygan-Ozaukee zone should be minimal since no coho were stocked in this area. Based on the data for 1981-83 (Table 10) these catch patterns did occur, with the highest catch in the Milwaukee-Kenosha zone (58.1%) and only 8.4% of the catch from the three zones north of the Sheboygan-Ozaukee zone.

TABLE 15. Distribution of catch among fisheries for each species within the Wisconsin waters of Lake Michigan (based on 1981-83 catch data; Append. Tables 1-5).

Fishery	Catch by Species (%)				
	Brook	Brown	Rainbow	Coho	Chinook
Trolling	6.4	40.1	25.8	78.0	50.9
Pier	37.8	22.1	26.6	13.6	6.2
Shore	23.8	23.3	21.2	2.6	4.2
Stream	32.0	14.5	26.4	5.8	38.7
Total	100.0	100.0	100.0	100.0	100.0

TABLE 16. Final stocking recommendations for the 1987 example developed from Tables 2-15 for the Wisconsin waters of Lake Michigan.

Management Zone	Brook Trout			Brown Trout			Rainbow Trout		
	Fingerlings	Yearlings	Total	Finglering	Yearlings	Total	Fingerlings	Yearlings	Total
Green Bay	5,300	15,700	21,000	101,200	102,100	203,300	83,500	72,800	156,300
Eastern Door	3,000	8,700	11,700	41,300	41,700	83,000	38,100	33,300	71,400
Kewaunee-Manitowoc	10,900	32,000	42,900	132,600	133,700	266,300	116,200	101,400	217,600
Sheboygan-Ozaukee	12,800	37,700	50,500	81,100	81,700	2,800	78,200	68,200	146,400
Milwaukee-Kenosha	4,300	12,600	16,900	86,000	86,600	72,600	87,200	76,100	163,300
Total	36,300	106,700	143,000	442,200	445,800	888,000	403,200	351,800	755,000

Management Zone	Chinook Salmon			Coho Salmon <sup>1</sup>		
	Fingerlings	Yearlings	Total	Finglering	Yearlings	Total
Green Bay	225,000	0	225,000	0	31,600	31,600
Eastern Door	146,000	0	146,000	0	0	0
Kewaunee-Manitowoc	452,000	0	452,000	0	126,400	126,400
Sheboygan-Ozaukee	335,000	0	335,000	0	94,800	94,800
Milwaukee-Kenosha	299,000	0	299,000	0	63,200	63,200
Total	1,457,000	0	1,457,000	0	316,000	316,000

<sup>1</sup>From example in Table 17.

The coho distribution procedure described here adopts this past management theory but allows options to stock north of the Sheboygan-Ozaukee zone (Table 17). The user of the stocking recommendation procedure must choose the most northern zone exclusive of Green Bay that is desired to be stocked with coho. In addition, the user must separately choose whether Green Bay is to be stocked or not. The proportion of the total number to be stocked in each zone is calculated as follows:

$$P_i = (200 / (n^2 + n)) * (n - (i-1))$$

where

$P_i$  = the proportion of the total number to be stocked in zone  $i$ .

$i$  = 1... $n$  where 1 is the northernmost zone and  $n$  is either Milwaukee-Kenosha or Green Bay.

$n$  = the total number of management zones to be stocked.

This procedure gives the Green Bay zone the smallest coho proportion since the catch performance of coho is unknown in this area. When more information is available, the distribution equation above may require revision.

TABLE 17. Example calculations used to establish stocking distributions for coho salmon within management zones in the Wisconsin waters of Lake Michigan. Management option chosen was to stock Green Bay and from Kewaunee-Manitowoc and south.

Management Zone	$i^1$	$n^2$	Stocking Priority Equation <sup>3</sup>	Stocking Distribution $P_i(\%)$
Green Bay	4	4	$P_4 = (200/(4^2 + 4)) (4 - (4-1))$	10
Eastern Door	--	--	--	--
Kewaunee-Manitowoc	1	4	$P_1 = (200/(4^2 + 4)) (4 - (1-1))$	40
Sheboygan-Ozaukee	2	4	$P_2 = (200/(4^2 + 4)) (4 - (2-1))$	30
Milwaukee-Kenosha	3	4	$P_3 = (200/(4^2 + 4)) (4 - (3-1))$	20

<sup>1</sup> $i = 1 \dots n$  where 1 is the northernmost zone and  $n$  is either Milwaukee-Kenosha or Green Bay.

<sup>2</sup> $n =$  the total number of management zones to be stocked.

<sup>3</sup> $P_i = (200/n^2 + n)(n - (i-1))$

The Lake Michigan stocking of chinook, coho, and rainbow trout must result in adequate numbers of mature adults returning to certain stocking sites for spawn collection purposes by the Wisconsin DNR. Fertilized eggs for hatchery propagation are collected at Strawberry Creek (eastern Door County) for chinook salmon, the Sheboygan River (Sheboygan-Ozaukee counties) for coho salmon, and the Oconto River (Green Bay) for rainbow trout. Management zones where these sites occur are given a stocking priority to insure an adequate return of mature fish to provide eggs for the hatchery program. Historically, Strawberry Creek has received approximately 10% of the total lakewide chinook stocking and adequate numbers of mature adults have returned to the stream. As a result, the distribution procedure minimally allocates 10% of the total chinook stocking to eastern Door County. A similar relationship cannot be defined for the collection of coho and rainbow eggs due to a lack of data. The distributional procedure, therefore, assumes the chinook stocking percentage (10%) for coho salmon in the Sheboygan-Ozaukee zone and for rainbow trout in the Green Bay zone. If these zones are not allocated 10% of the annual stocking for these species, then equal proportions are deducted from the other zones and added to the zones where spawn collection occurs.

The lake trout available for stocking are distributed among three lake trout rehabilitation zones: the Clay Banks zone, Mid-Lake Reef zone, and Kewaunee-Kenosha zone as defined by Krueger and Dehring (1986). These rehabilitation zones are approximately equivalent to the inshore waters of Eastern Door and Kewaunee counties (for Clay Banks), the offshore waters of Sheboygan, Ozaukee and Milwaukee counties (for Mid-Lake Reef) and the inshore waters of Kewaunee County south to Kenosha County (for Kewaunee-Kenosha). Distribution of the lake trout among the three rehabilitation zones use the proportions proposed by Krueger and Dehring (1986) and are based on the available spawning reef area and expected total mortality rates. These stocking proportions are 0.21 to the Clay Banks zone, 0.50 to the Mid-Lake zone, and 0.29 to the Kewaunee-Kenosha zone and are multiplied by the lake trout number specified as available for stocking (Table 18).

TABLE 18. Example calculation to determine the distribution of lake trout among three rehabilitation zones in the Wisconsin waters of Lake Michigan.

Rehabilitation Zone	Lake Trout <sup>1</sup> Available (numbers)	Distribution <sup>2</sup> Proportion	Recommended Stocking (numbers)
Clay Banks	1,000,000	0.21	210,000
Mid-Lake Reef	1,000,000	0.50	500,000
Kewaunee-Kenosha	1,000,000	0.29	290,000

<sup>1</sup>Lake trout available from the U.S. Fish and Wildlife Service; specified by the user of the stocking recommendation procedure.

<sup>2</sup>Proportion given by Krueger and Dehring (1986).

## PREDICTED CATCH

The salmonid catch exclusive of lake trout that will occur as a result of the stocking within management zones is predicted by multiplying the recommended stocking numbers (Table 16) by the catch/stock ratio for each species (Table 3). The product equals the catch of each species within the management zones (Table 19). This predicted catch will allow fisheries managers within each zone to determine the potential fisheries impact of the recommended stocking in their geographical area of responsibility. The sum of the predicted catches among zones equals the total catch for each species. The total catch prediction allows a comparison of the management impact of the recommended stocking versus the originally specified catch objective (Table 19).

Catch by fishery type (trolling, pier, shore, stream) for the Wisconsin waters of Lake Michigan is predicted by multiplying the proportion of a species catch that occurs in each fishery (Table 15) by the total catch predicted for each species (Table 20). These predictions allow comparison to lakewide management objectives set by species and fishery (e.g., rainbow trout catch in streams).

The predicted catches by zone or fishery described above could occur over a period up to 4-5 years from the date of stocking since some salmonids (e.g., chinook salmon) will contribute to the fishery for several years after stocking. The predicted catch would approximate the annual catch if the recommended annual stocking was conducted for a 5-year period.

TABLE 19. Predicted catch by management zone from the example recommended 1987 stocking levels (from Table 16) for the Wisconsin waters of Lake Michigan.

Management Zone	Predicted Catch (numbers)					Total
	Brook	Brown	Rainbow	Chinook	Coho	
Green Bay	900	11,000	5,700	22,200	8,200	48,000
Eastern Door	500	4,300	2,600	14,400	0	21,800
Kewaunee-Manitowoc	1,800	13,800	7,900	44,600	33,000	101,100
Sheboygan-Ozaukee	2,200	8,400	5,300	33,000	24,700	73,600
Milwaukee-Kenosha	700	8,900	6,000	29,500	16,500	61,600
Total	6,100	46,400	27,500	143,700	82,400	306,100
Catch Objective <sup>1</sup>	12,000	90,000	54,000	282,000	162,000	600,000
Deviation from Objective						
Numbers	-5,900	-43,600	-26,500	-138,300	-79,600	-293,900
Percentage	49%	49%	49%	49%	49%	49%

<sup>1</sup>From Table 2.

TABLE 20. Predicted catch by fishery from the example recommended 1987 stocking levels (from Table 16) for the Wisconsin waters of Lake Michigan.

Management Zone	Predicted Catch (numbers)					Total
	Brook	Brown	Rainbow	Chinook	Coho	
Trolling	400	18,600	7,100	73,100	64,300	163,500
Pier	2,300	10,300	7,300	8,900	11,200	40,000
Shore	1,500	10,800	5,800	6,100	2,100	26,300
Stream	1,900	6,700	7,300	55,600	4,800	76,300
Total	6,100	46,400	27,500	143,700	82,400	306,100

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APPENDIX TABLE 1. Brook trout catch by fishery and zone in the Wisconsin waters of Lake Michigan, 1981-83.

Fishery	Green Bay		Eastern Door		Kewaunee-Manitowoc		Sheboygan-Ozaukee		Milwaukee-Kenosha		Average 1981-83	Catch Distribution Among Fisheries					
	1981	1982	1983	1981	1982	1983	1981	1982	1983	1981			1982	1983			
Trotting	233	40	0	161	134	27	347	0	16	49	120	166	0	0	22	438	6.4%
Pier	0	0	0	348	0	124	441	247	1,305	1,022	3,022	1,161	29	0	7	2,569	37.8%
Shore	0	0	0	617	59	0	48	203	96	82	3,669	66	0	0	0	1,613	23.8%
Stream	165	0	0	59	0	0	830	632	737	485	3,135	468	0	0	0	2,170	32.0%
Total	398	40	0	1,185	193	151	1,666	1,082	2,154	1,638	9,946	1,861	29	0	29	6,791	100.0%
Average 1981-83		146			510		1,634			4,482			19				
Catch Distribution Among Zones		2.1%			7.5%		24.1%			66.0%						0.3%	

APPENDIX TABLE 2. Brown trout catch by fishery in the Wisconsin waters of Lake Michigan, 1981-83.

Fishery	Green Bay		Eastern Door		Kewaunee-Manitowoc		Sheboygan-Ozaukee		Milwaukee-Kenosha		Average 1981-83	Catch Distribution Among Fisheries					
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982							
Trotting	11,020	7,429	13,890	4,325	3,288	5,036	3,591	7,099	2,740	1,544	2,127	2,796	2,556	2,626	5,109	25,059	40.1%
Pier	7,629	1,017	1,417	94	1,071	172	2,980	2,246	4,118	3,945	6,217	2,710	2,310	2,076	3,460	13,821	22.1%
Shore	1,921	1,177	4,152	2,863	226	419	3,734	13,964	3,400	2,136	2,101	4,793	178	573	1,973	14,537	23.3%
Stream	2,055	2,598	3,052	489	139	81	4,113	891	3,953	2,206	5,267	78	1,219	1,078	0	9,073	14.5%
Total	22,625	12,221	22,511	7,771	4,724	5,708	14,418	24,200	14,211	9,831	15,712	10,377	6,263	6,353	10,542	62,489	100.0%
Average 1981-83		19,119			6,068		17,610			11,973				7,719			
Catch Distribution Among Zones		30.6%			9.7%		28.2%			19.2%				12.3%			

APPENDIX TABLE 3. Rainbow trout catch by fishery and zone in the Wisconsin waters of Lake Michigan, 1981-83.

Fishery	Green Bay		Eastern Door		Kewaunee-Manitowoc		Sheboygan-Ozaukee		Milwaukee-Kenosha		Average 1981-83	Catch Distribution Among Fisheries
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982		
Trolling	855	245	609	163	1,392	830	1,408	2,183	2,337	3,022	6,870	25.8%
Pier	5,320	216	934	665	2,676	862	2,712	2,028	1,723	380	7,078	26.6%
Shore	2,422	0	2,443	810	1,428	782	751	1,567	487	786	5,646	21.2%
Stream	231	3,065	489	1,848	2,723	1,871	869	1,808	1,695	2,821	7,039	26.4%
Total	8,828	3,526	4,475	3,486	8,219	4,345	5,740	7,586	6,242	7,009	26,633	100.0%
Average 1981-83	4,772		2,779		6,101		7,112			5,868		
Catch Distribution Among Zones	17.9%		10.5%		22.9%		26.7%			22.0%		

APPENDIX TABLE 4. Chinook salmon catch by fishery and zone in the Wisconsin waters of Lake Michigan, 1981-83.

Fishery	Green Bay		Eastern Door		Kewaunee-Manitowoc		Sheboygan-Ozaukee		Milwaukee-Kenosha		Average 1981-83	Catch Distribution Among Fisheries
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982		
Trolling	2,220	7,224	5,939	5,093	17,405	25,512	32,141	31,359	28,567	25,840	100,417	50.9%
Pier	193	116	96	201	3,403	2,763	3,737	3,269	516	2,804	12,278	6.2%
Shore	8,077	466	2,497	738	98	2,387	122	488	268	464	8,341	4.2%
Stream	18,878	47,497	13,575	931	31,567	16,174	23,797	10,837	6,139	3,502	76,320	38.7%
Total	29,368	55,303	22,107	7,517	52,473	45,836	59,797	45,953	35,490	32,610	197,356	100.0%
Average 1981-83	35,593		8,482		53,035		56,137			44,110		
Catch Distribution Among Zones	18.0%		4.3%		26.9%		28.4%			22.4%		

APPENDIX TABLE 5. Coho salmon catch by fishery and zone in the Wisconsin waters of Lake Michigan, 1981-83.

Fishery	Green Bay		Eastern Door		Kewaunee-Manitowoc		Sheboygan-Ozaukee		Milwaukee-Kenosha		Average 1981-83	Catch Distribution Among Fisheries					
	1981	1982	1983	1981	1982	1983	1981	1982	1983	1981			1982	1983			
Trolling	333	0	0	319	1,838	400	1,491	6,388	2,373	15,227	19,166	8,784	33,453	60,868	11,101	53,914	78.0%
Pier fishing	0	0	0	0	0	19	292	1,450	1,434	4,980	7,634	2,352	2,183	5,208	2,599	9,384	13.6%
Shore	0	0	0	82	0	73	37	63	65	618	1,584	1,369	532	153	733	1,770	2.6%
Stream	0	0	156	70	0	0	462	142	105	2,983	4,498	167	2,633	503	396	4,038	5.8%
Total	333	0	156	471	1,838	492	2,282	8,043	3,977	23,808	32,882	12,672	38,801	66,732	14,829	69,105	100.0%
Average 1981-83	163			934				4,767		23,121				40,121			
Catch Distribution Among Zones		0.2%		1.3%				6.9%		33.5%				58.1%			

APPENDIX TABLE 6. Lengths of Wisconsin's Lake Michigan tributary streams that contribute to the salmonid fishery.

Management Zone	Stream Name	Stream Length (miles)
Green Bay	Menominee River	2.2
	Little River	1.5
	Peshtigo River	6.6
	Oconto River <sup>1</sup>	2.2
	Chicken Shack Creek <sup>1</sup>	13.5
	Little River <sup>1</sup>	12.5
	Kelly Brook <sup>1</sup>	<u>12.8</u>
Total		51.3
Eastern Door	Rieboltz Creek <sup>1</sup>	0.7
	Heins Creek <sup>1</sup>	0.7
	Hibbard Creek <sup>1</sup>	2.3
	Whitefish Bay Creek <sup>1</sup>	1.1
	Shivering Sands Creek <sup>1</sup>	<u>0.6</u>
Total		5.4
Kewaunee-Manitowoc	Stoney Creek <sup>1</sup>	4.5
	Ahnapee River	6.6
	Silver Creek	2.1
	Threemile Creek <sup>1</sup>	0.3
	Mashek Creek <sup>1</sup>	1.1
	Kewaunee River <sup>2</sup>	12.0
	Little Scarboro Cr. <sup>3</sup>	1.5
	Casco Creek <sup>3</sup>	1.4
	Rogers Creek <sup>3</sup>	0.8
	Scarboro Creek <sup>3</sup>	4.0
	Molash Cr. <sup>1</sup>	3.5
	East Twin River	8.4
	West Twin River	5.6
	Little Manitowoc River	2.7
	Manitowoc River <sup>4</sup>	18.4
	Branch River <sup>1</sup>	16.8
	Silver Creek <sup>1</sup>	0.6
	Pine Creek <sup>1</sup>	0.4
	Point Creek <sup>1</sup>	0.8
	Fischer Creek <sup>1</sup>	0.8
	Centerville Creek <sup>1</sup>	<u>0.2</u>
Total		84.8
Sheboygan-Ozaukee	Sevenmile Creek	2.5
	Meeme Creek	0.8
	Pigeon River	15.4
	Sheboygan River	8.6
	Weedens Creek	1.5
	Black River <sup>1</sup>	2.8
	Sucker Creek <sup>1</sup>	1.7
	Sauk Creek <sup>1</sup>	<u>0.8</u>
Total		34.1
Milwaukee-Kenosha	Milwaukee River	3.0
	Oak Creek	0.8
	Root River <sup>1</sup>	5.6
	Pike River	<u>1.6</u>
Total		11.0
Grand Total		186.6

<sup>1</sup>Snagging not allowed.

<sup>2</sup>Stream length downstream from designated trout water.

<sup>3</sup>Designated trout stream. Fishing is not allowed October-April. Stream length not included in totals.

<sup>4</sup>Snagging is allowed in the lower 4.2 miles.

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